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Implementing principles of the integrated control concept 50 years later – current challenges in IPM for arthropod pests

1 INTEGRATED CONTROL CONCEPT

The 1959 publication of the article 'The Integrated Control Concept' by Stern and colleagues[1] established a new philosophical framework for pest management that eventually provided a foundation for IPM to develop. Considered within the context of pest control approaches 50 years ago, the integrated control concept radically departed from the undisciplined and at times unrestrained use of pesticides for controlling pest populations. Stern and his California colleagues had been concerned about the deleterious, broad-spectrum effects of pesticides in agriculture for some years,[2–4] but with no framework available to address the critical issue of when to treat with an insecticide if pest infestations were inadequately suppressed by natural control. It was through the development of dual theoretical constructs, economic injury level (EIL) and economic threshold (ET), that Stern *et al.*[1] devised a pragmatic and sensible means of integrating chemical and biological control. However, the enduring impact of the integrated control concept is also due to other novel perspectives that these authors brought to pest management in their historic article. Their broad experience in the field and innovative insights into landscape ecology contributed to a unique understanding of pest dynamics and also provided a practical knowledge of the challenging decisions faced by growers concerned with protecting their crops. By combining a theoretical basis of insect management, represented by EIL and ET, with a realistic view of pest populations as potentially destructive agents of crops and ultimately grower livelihoods, Stern and colleagues[1] formalized the integrated control concept into a robust theory of pest management that continues to serve modern IPM in both theory and practice.

2 IPM CHALLENGES

2.1 Regulatory inconsistencies

In spite of the wide perspective and completeness of approach advanced in the integrated control concept, situations occur in pest management today in which the integration of multiple control tactics is compromised by circumstances beyond the immediate goal of suppressing pest infestations. Many of the challenges facing IPM involve broader issues that are external to the farm. The rapid rise of the global marketplace has created new opportunities for individual growers and agricultural conglomerates, but not without new trading regulations that directly impact pest management decisions made by the grower. One of the more contentious issues has been the absolute nature of maximum residue levels (MRLs) as they apply to fresh produce destined for export markets. Regulatory agencies of various nations have established MRLs as a means of safeguarding imported food by avoiding excessive residues of pesticides. However, many newer insecticides, after successfully completing rigorous registration procedures through the United States Environmental Protection Agency (USEPA) and being launched into the marketplace, are precluded from use on crops in which MRLs have not been established by specific foreign markets. In addition to having the potential to occasionally impede international trade, such regulations can also result in substandard IPM if the choice of chemical treatments is limited by the absence of MRLs for particular compounds.[5] Although the effect this has on IPM practices is situational, depending on the particular crop and pest complex, it can have profound consequences if established insecticides are not performing adequately owing to resistance, and safer and more effective newer insecticides cannot be integrated into existing management programs because of residue restrictions in the destination country.

2.2 Consumer expectations

Implementation of IPM is increasingly challenged by the high cosmetic standards for both fresh and processed produce as well as for other horticultural commodities such as fresh flowers. The establishment of progressively lower thresholds for pest damage, as noted by Stern *et al.*,[1] has become zero tolerance for many produce items.[6] The market demand for cosmetically flawless produce undoubtedly had its origins early in the synthetic pesticide era when powerful new products dazzled the pest management community, farmers and consumers by making it easier to reduce pest damage and ushering in higher quality standards for fresh and processed food and fiber products. The irony is that it also helped to create a whole new set of pest management problems associated with intensive pesticide use that have plagued agriculture for decades. However, there has been no relaxation of the stringent market standards for produce, leaving growers few options other than to deliver cosmetically flawless produce to meet market expectations. As a result, extraordinary pressure is placed on growers to deliver perfect produce without regard to the ideals of the integrated control concept, putting into jeopardy the sustainability of IPM.

2.3 Invasive species

Another outcome of the global marketplace has been the redistribution of pest species from one geographical region, or one production system, to another. The impact of broadside invasions into new regions has been profound in some cases, often with permanent repercussions even after readjustments in pest control have been made. Not only are the pests themselves transported to new regions, often in the absence of their natural enemies, but pathogens vectored by certain invasive species or resistance genes carried by pest species create a potentially more serious problem than the pest itself, at least in the case of pathogen introduction. Recent examples include the invasion and establishment of the

Asian citrus psyllid, *Diaphorina citri* Kuwayama, first to Brazil and then to Florida, along with the pathogen *Candidatus Liberibacter asiaticus* and other causal agents of huanglongbing (HLB) or yellow shoot disease.[7,8] The rapidly spreading HLB constitutes a major crisis for citrus production and has elicited an intensive search for viable management solutions. With respect to the movement of resistance genes, the invasion of multiple continents by *Bemisia tabaci* (Genn.) biotype Q has been a concern because of its well-documented incidence of multiple insecticide resistance.[9,10] Other examples of invasive pests that have severely impacted upon agriculture are virtually innumerable, many of them having been established in non-native territory for so long that they are scarcely thought of as invasive pests any longer. In some cases, the required use of insecticides as part of a phytosanitary export program has led to breakdowns in IPM.[11] Unfortunately, with increasing globalization, invasive species will continue to create significant problems that are likely to become worse and present unique challenges for agricultural production and IPM in the future.

2.4 Practicing information-driven IPM

The integrated control concept represented a skillful solution for the problems and uncertainties associated with initiating chemical control action against a pest population. However, to put into practice economic decision levels required instruction and training not only to grasp the concept but also to execute in a literal manner to achieve the fullest integration of control methods. Stern *et al.*[1] recognized the complexity of the concept and recommended supervised control, involving a professional entomologist, to implement the tenets of the integrated control concept at the local level. The same decision-making framework exists today as the foundation of IPM for arthropod pests and still requires well-trained decision-makers to execute correctly. The challenge has become even greater, as newer insecticide modes of actions exhibiting high selectivity and protracted response patterns of target populations require a more thorough understanding to implement proficiently and to use in a diversified scheme for managing resistance.[12] As the demand has increased for knowledgeable individuals who are capable of integrating multifaceted controls in a rigorous IPM program, institutional support has declined through the loss of extension-related positions in land-grant universities in the USA.[11–14] Erosion at the top of the trickle-down structure responsible for knowledge transfer to the field is one of the most serious threats to IPM. Its transition from a knowledge-driven discipline backed by scientifically validated findings to an ad hoc collection of pest management tactics applied in an uncoordinated manner is not the vision that was detailed in the integrated control concept. A continuing decline in progressive IPM programs conceived and developed in the university may result in less guidance from university researchers and extension agents and lead to greater dependence on private consulting firms. The risk here is that the potential is increased for greater emphasis to be placed on conservative approaches that depend more on pesticides as a means to achieve certainty in pest control outcomes.

3 LOOKING FORWARD

Advances in biotechnology and pesticide discovery in recent decades have greatly improved the tool set available to pest managers. While no ceiling has been reached in terms of possibilities for engineering new antipest mechanisms or discovering new modes of action, the perennial warning about a finite number of measures available to control pest populations is nevertheless as pertinent now as at any time in the past 50 years. The pest management community is therefore compelled to make the most of what we have today without succumbing to the possibility of tomorrow. As with so many other complex issues confronting humankind, knowledge and objectivity in our approach to safeguarding the world's food supply requires that tactics employed against pestiferous competitors be scientifically based, economically sensible and ecologically sustainable. The conceptual model put forth 50 years ago by Stern *et al.*[1] still describes the most rational and knowledgeable approach to managing crop pests by incorporating economic damage thresholds to avoid unnecessary treatments with pesticides, instead allowing natural control the opportunity to suppress damaging infestations. It is therefore timely and appropriate for the current *In Focus* section to consider examples from various crop and pest systems and examine the role and impact of the integrated control concept in IPM today.

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